EXHIBIT D

Economics: Private and Public Choice

Tenth Edition

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should be kept in mind. First, business decision makers are likely to choose the simplest route to economic gain. Generally, it is easier for business firms to cater to the actual desires of consumers than to attempt to reshape their preferences or persuade them to purchase an undesired product. Second, when advertising influences preferences, does it follow that this is bad? College classes in music and art appreciation, for example, may also change preferences for various forms of art and music. Does this make them bad? Economic theory is neutral. It neither condemns nor defends advertising—or college classes—as they try to change the tastes of target audiences.

From market demand and the preferences that lie behind it, we turn now to the measurement of buyer and seller responsiveness to market changes. Intelligent pricing decisions for businesses, universities, and individuals depend on the ability of decision makers to understand this responsiveness and even in some cases to look for measures of buyer responses. The same is true for government decision makers considering tax changes.

ELASTICITY OF DEMAND

Buyers will predictably demand fewer units when the price rises. If a university raises tuition, fewer students will enroll. How many fewer? That depends on a number of factors, including the available substitutes, the cost of change, and the time available to make the change. Entering freshmen may be more responsive to the price change than seniors who would have trouble transferring credits to another school. Students wanting a specific program that is unavailable other places may also be less responsive to the tuition change.

Similarly, when electricity prices rise, as they recently did in California, consumers will buy less. Per-person consumption of electricity there is already the lowest in the nation, but much more conservation is possible. How responsive will consumers be to a specific change in the price of electricity? Again, many factors will enter, from the options available to consumers to the period of time we want to consider. Consumer response to a specific price increase will be greater over a five-year period than a five-week period. Over time, users can gradually replace appliances, lighting fixtures, and water heaters with energy-saving models, learn the habit of switching off unused lights and computers, or switch from electric to gas heat, all in response to the higher electricity price. Estimating short- and long-run responses to a change in price is crucial for government regulators and for electric utility managers.

To learn about and describe buyer responsiveness to price change, economists have developed a concept called *elasticity*. The responsiveness of buyers to a change in price is measured by the **price elasticity of demand**, defined as:

Price elasticity of demand
The percent change in the quantity of a product demanded divided by the percent change in the price causing the change in quantity. Price elasticity of demand indicates the degree of consumer response to variation in price.

$$\text{Price elasticity of demand} = \frac{\text{Percentage change in quantity demanded}}{\text{Percentage change in price}} = \frac{\%\Delta Q}{\%\Delta P}$$

This ratio is often called the *elasticity coefficient*. To express it more briefly, we use the notation $\%\Delta Q$ to represent percent change in quantity and $\%\Delta P$ to represent percent change in price. (The Greek letter delta (Δ) means "change in.") The law of demand states that an increase in price lowers quantity purchased, while a decrease in price raises it. Because a change in price causes the quantity demanded to change in the opposite direction, the price elasticity coefficient is always negative, although economists often ignore the sign and simply use the absolute value of the coefficient.

To see how the concept of elasticity works, suppose that the price of the Ford Taurus rose 10 percent, while other prices remained the same. Ford could expect Taurus sales to fall substantially—perhaps 30 percent—as car buyers responded by switching to the many competing cars whose price had not changed. The strong responsiveness of buyers means that the demand for the Taurus is elastic.

Now consider a different situation. Suppose that because of a new tax, the price of not only the Taurus *but all new cars* rises 10 percent. Consumer options in responding to *this* price increase are much more limited. They can't simply switch to a cheaper close substi-

tute, as they could if the price of the Taurus alone rose. They might either simply pay the extra money for a new car or settle for a used car instead. The 10 percent rise in the price of all new cars will lead to a smaller response, perhaps a 5 percent decline in sales of new cars.

To calculate the elasticity coefficient for the Taurus in our example above, we begin with the 30 percent decline in quantity demanded, and divide by the 10 percent rise in the price that caused the decline. Thus, the elasticity of demand for the Taurus would be:

$$\frac{\%\Delta\text{Quantity}}{\%\Delta\text{Price}} = \frac{-30\%}{+10\%} = -3$$

(or 3.0 if we ignore the minus sign), implying that the percentage change in quantity demanded is three times the percentage change in price.

To calculate the demand elasticity for *all* cars (our second example), we see that the percentage change in quantity, 5 percent, divided by the percentage change in price, 10 percent, gives us $-\frac{1}{2}$, or -0.5. The price elasticity of demand for all cars implies that the percentage change in quantity is half the percentage change in price, using our hypothetical numbers.

To calculate elasticity, we usually begin with the quantities purchased at different prices and first compute the percentage changes. Suppose we begin with a price change from P_0 to P_1, which causes a change in quantity demanded, from Q_0 to Q_1. The change in quantity demanded is $Q_0 - Q_1$. To calculate the percentage change in quantity we divide the actual change by the midpoint (or average) of the two quantities.[9] Although it is often easy to find the midpoint without a formula (halfway between \$4 and \$6 is \$5), it can also be found as $(Q_0 + Q_1)/2$. Finally, because 0.05 is simply 5 percent, we multiply by 100. Thus, we may express the percentage change in quantity demanded as:

$$\frac{Q_0 - Q_1}{(Q_0 + Q_1)/2} \times 100$$

Similarly, when the change in price is $P_0 - P_1$, the *percentage* change in price is

$$\frac{P_0 - P_1}{(P_0 + P_1)/2} \times 100$$

Dividing the resulting percentage change in quantity by the percentage change in price gives the elasticity.

Using these expressions for the percentage changes suggests a more direct method of computing elasticity from the numbers. Dividing the percentage change in quantity by the percentage change in price and simplifying gives

$$\frac{(Q_0 - Q_1)/(Q_0 + Q_1)}{(P_0 - P_1)/(P_0 + P_1)}$$

(Because each term is multiplied by 100 and the denominator of each term contains a 2, these factors cancel out of the final expression.)

A numerical example may help to illustrate. Suppose that Trina's Cakes can sell 50 specialty cakes per week at \$7 each, or 70 of the cakes at \$6 each. The percentage difference in quantity is the difference in the quantity ($50 - 70 = -20$), divided by the midpoint (60), times 100. The result is a -33.33 percent change in quantity ($-20 \div 60 \times 100 = -33.33$). The percentage change in price is the difference in price (\$7 − \$6 = \$1) divided by the midpoint price (\$6.50) times 100, or a 15.38 percent change in price ($1 \div 6.5 \times 100 = 15.38$).

[9]This formula uses the average of the starting point and the ending point of the change so that it will give the same result whether we start from the lower or the higher price. This arc elasticity formula is not the only way to calculate elasticity, but it is the most frequently used.

Dividing the percentage change in quantity by the percentage change in price ($-33.33 \div 15.38$) gives an elasticity coefficient of -2.17. Alternatively, we could have expressed this directly as:

$$\frac{[(50-70)/(50+70)]}{[(7-6)/(7+6)]} = \frac{-20/120}{1/13} = \frac{-1/6}{1/13} = \frac{-13}{6} = -2.17$$

The same result is obtained either way. The elasticity of -2.17 indicates that the percentage change in quantity is just over twice the percentage change in price.

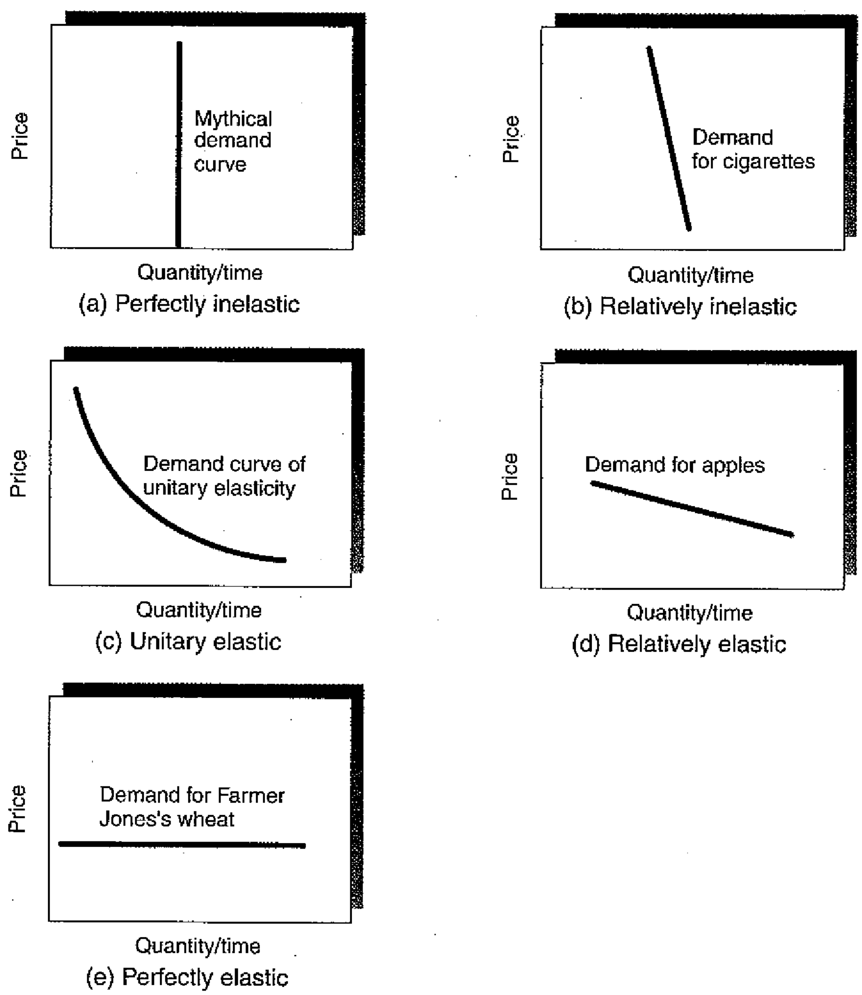
The elasticity coefficient lets us make a precise distinction between elastic and inelastic. When the elasticity coefficient is greater than 1 (ignoring the sign), as it was for the demand for Trina's Cakes, demand is elastic. When it is less than 1, demand is inelastic. Demand is said to be of *unitary elasticity* if the price elasticity is exactly 1.

Graphic Representation of Price Elasticity of Demand

Exhibit 3 presents demand curves of varying elasticity. A demand curve that is completely vertical is termed *perfectly inelastic*. In the real world, such a demand is nonexistent. The substitutes for a good become more attractive as the price of that good rises, and since the income effect is also present, we should expect that a higher price will always reduce

EXHIBIT 3
Elasticity of Demand

a) Perfectly inelastic: Despite an increase in price, consumers still purchase the same amount. In fact, the substitution and income effects prevent this from happening in the real world.
b) Relatively inelastic: A percent increase in price results in a smaller percent reduction in sales. The demand for cigarettes has been estimated to be highly inelastic.
c) Unitary elastic: The percent change in quantity demanded is equal to the percent change in price. A curve of decreasing slope results. Sales revenue (price times quantity sold) is constant.
d) Relatively elastic: A percentage increase in price leads to a larger percent reduction in purchases. When good substitutes are available for a product (as in the case of apples), the amount purchased will be highly sensitive to a change in price.
e) Perfectly elastic: Consumers will buy all of Farmer Jones's wheat at the market price, but none will be sold above the market price.



quantity demanded, other things remaining the same. Still, the (mythical) perfectly inelastic demand curve is shown in part a of Exhibit 3.

The more inelastic the demand, the steeper the demand curve *over any specific price range*. Inspection of the demand for cigarettes (part b of Exhibit 3), which is highly inelastic, and the demand for apples (part d), which is relatively elastic, indicates this. When demand elasticity is unitary, as part c illustrates, a demand curve that is convex to the origin will result. When a demand curve is completely horizontal, an economist would say that it is *perfectly elastic*. Demand for the wheat marketed by a single wheat farmer, for example, would approximate perfect elasticity (part e).

Because elasticity is a relative concept, the elasticity of a straight line demand curve will differ at each point along the demand curve. As **Exhibit 4** illustrates, the elasticity of a straight line demand curve (one with a constant slope) will range from highly elastic to highly inelastic. Here, when the price rises from \$10 to \$11, sales decline from 20 to 10. According to the formula, the price elasticity of demand is −7.0. Demand is very elastic in this region. In contrast, demand is quite inelastic in the \$1 to \$2 price range. As the price increases from \$1 to \$2, the amount demanded declines from 110 to 100. The 10-unit change in quantity is the same, but it is a smaller *percentage* change. And the \$1 change in price is the same, but it is now a larger *percentage* change. The elasticity of demand in this range is only −0.14; demand here is highly inelastic.

It is clear now that elasticity is more than just the slope of the demand curve. This is important because unlike the slope, elasticities are independent of the units of measure. The elasticity is the same whether we talk about dollars per gallon or cents per liter, even though the slope changes. Elasticity is the appropriate measure, because people do not care what units of measurement are used; their response depends on the actual terms of exchange.

How large is the price elasticity of demand for various goods? What determines those elasticities? The next section reports some estimates and steps back to explain them.

Price Elasticities and Their Determinants

Economists have estimated the price elasticity of demand for many products. As **Exhibit 5** illustrates, the elasticity of demand varies substantially among products. The demand is highly inelastic for several products—salt, toothpicks, matches, light bulbs, and newspapers,

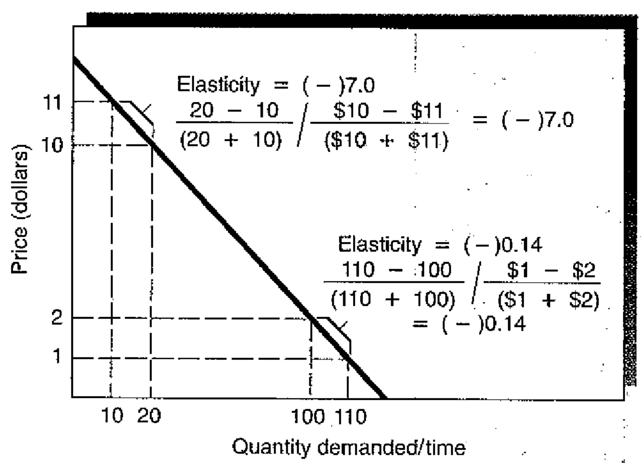


EXHIBIT 4
Slope of Demand Curve Versus Price Elasticity

With this straight line (constant slope) demand curve, demand is more elastic in the high price range. The formula for arc elasticity shows that, when price rises from \$1 to \$2 and quantity falls from 110 to 100, demand is inelastic. A price rise of the same magnitude (but of a smaller percentage), from \$10 to \$11, leads to a decline in quantity of the same size (but of a larger percentage), so that elasticity is much greater. (Price elasticities are negative, but economists often ignore the sign and look only at the absolute value.)

EXHIBIT 5
Estimated Price Elasticity of Demand for Selected Products

Product	Elasticity
INELASTIC	
Salt	−0.1
Matches	−0.1
Toothpicks	−0.1
Airline travel, short run	−0.1
Gasoline, short run	−0.2
Gasoline, long run	−0.7
Residential natural gas, short run	−0.1
Residential natural gas, long run	−0.5
Coffee	−0.25
Fish (cod), consumed at home	−0.5
Tobacco products, short run	−0.45
Legal services, short run	−0.4
Physician services	−0.6
Dental services	−0.7
Taxi, short run	−0.6
Automobiles, long run	−0.2
APPROXIMATELY UNITARY ELASTICITY	
Movies	−0.9
Housing, owner occupied, long run	−1.2
Shellfish, consumed at home	−0.9
Oysters, consumed at home	−1.1
Private education	−1.1
Tires, short run	−0.9
Tires, long run	−1.2
Radio and television receivers	−1.2
ELASTIC	
Restaurant meals	−2.3
Foreign travel, long run	−4.0
Airline travel, long run	−2.4
Fresh green peas	−2.8
Automobiles, short run	−1.2–1.5
Chevrolet automobiles	−4.0
Fresh tomatoes	−4.6

Sources: Hendrick S. Houthakker and Lester D. Taylor, *Consumer Demand in the United States, 1929–1970* (Cambridge: Harvard University Press, 1966, 1970); Douglas R. Bohi, *Analyzing Demand Behavior* (Baltimore: Johns Hopkins University Press, 1981); Hsaing-tai Cheng and Oral Capps Jr., "Demand for Fish," *American Journal of Agricultural Economics*, August 1988; U.S. Department of Agriculture; and Rexford E. Santerre and Stephen P. Neun, *Health Economics: Theories, Insights and Industry Studies* (Orlando: Harcourt, 2000).

for example—in their normal price range. On the other hand, the demand curves for fresh tomatoes, Chevrolet automobiles, and fresh green peas are highly elastic. The primary factors explaining this variation are the availability of good substitutes and to some extent the share of the typical consumer's total budget expended on a product.

Availability of Substitutes

The most important determinant of the price elasticity of demand is the availability of substitutes. When good substitutes for a product are available, a price rise induces many consumers to switch to other products. Demand is elastic. For example, if the price of felt tip pens increased, many consumers would simply switch to pencils, ballpoint pens, or (for children) crayons. If the price of apples increased, consumers might substitute oranges, bananas, peaches, or pears.

When good substitutes are unavailable, the demand for a product tends to be inelastic. Medical services are an example. When we are sick, most of us find witch doctors, faith healers, palm readers, and aspirin to be highly imperfect substitutes for the services of a physician. Not surprisingly, the demand for physician services is inelastic.

The availability of substitutes increases as the product class becomes more specific, thus increasing price elasticity. For example, as Exhibit 5 shows, the price elasticity of Chevrolets, a narrow product class, exceeds that of the broad class of automobiles in general. If the price of Chevrolets alone rises, many substitute cars are available. But if the prices of all automobiles rise together, consumers have fewer good substitutes.

Share of Total Budget Expended on Product

If the expenditures on a product are quite small relative to the consumer's total budget, the income effect will be small even if there is a substantial increase in the price of the product. This will make demand less elastic. Compared to one's total budget, expenditures on some

commodities are almost inconsequential. Matches, toothpicks, and salt are good examples. Most consumers spend only $1 or $2 per year on each of these items. A doubling of their price would exert little influence on the family budget. Therefore, even if the price of such a product were to rise sharply, consumers would still not find it in their interest to spend much time and effort looking for substitutes.

Exhibit 6 provides a graphic illustration of both elastic and inelastic demand curves. In part a, the demand curve for ballpoint pens is elastic, because there are good substitutes—for example, pencils and felt tip pens. Therefore, when the price of the pens increases from $1.00 to $1.50, the quantity purchased declines sharply from 100,000 to only 25,000. The calculated price elasticity equals −3.0. The fact that the absolute value of the coefficient is greater than 1 confirms that the demand for ballpoint pens is elastic over the price range illustrated.

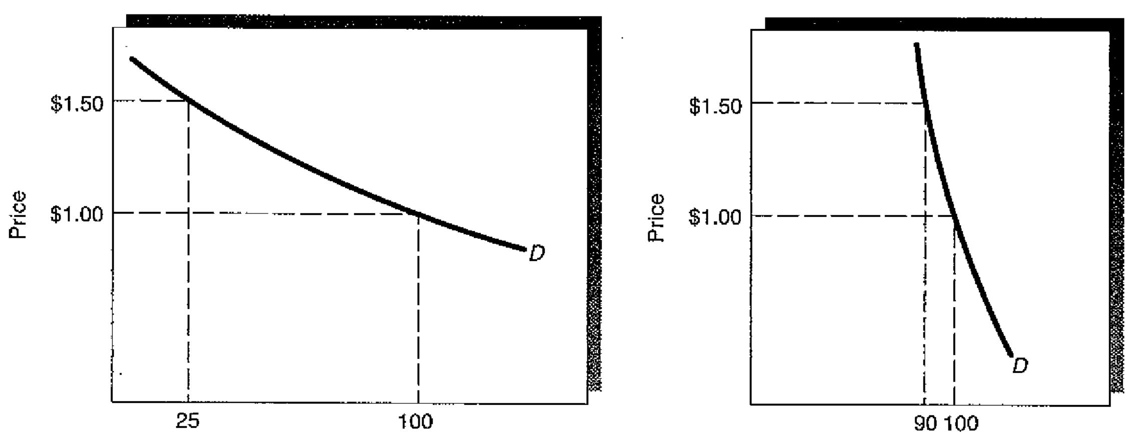
Part b of Exhibit 6 illustrates the demand curve for cigarettes. Because most smokers do not find other products to be a good substitute, the demand for cigarettes is highly inelastic. If a unit of six cigarettes is worth a dollar, a substantial (from $1.00 to $1.50) increase in price leads to only a small reduction in quantity demanded. The price elasticity coefficient is −0.26, substantially less in absolute value than 1, confirming that the demand for cigarettes is inelastic. (*Exercise:* Use the price elasticity formula to verify the values of these elasticity coefficients.)

Time and Demand Elasticity

As changing market conditions raise or lower the price of a product, both consumers and producers will respond. However, their response will not be instantaneous, and it is likely to become larger over time. ***In general, when the price of a product increases, consumers will reduce their consumption by a larger amount in the long run than in the short run. Thus, the demand for most products will be more elastic in the long run than in the short run. This relationship between the elasticity coefficient and the length of the adjustment period is sometimes referred to as the second law of demand.***

EXHIBIT 6
Inelastic and Elastic Demand

As the price of ballpoint pens (a) rose from $1.00 to $1.50, the quantity purchased plunged from 100,000 to 25,000. The percent reduction in quantity is larger than the percent increase in price. Thus, the demand for the pens is elastic. In contrast, an increase in the price of cigarettes from $1.00 to $1.50 results in only a small reduction in the number purchased (b). Reflecting the inelasticity of demand for cigarettes, the percent reduction in quantity is smaller than the percent increase in price.



(a) Ballpoint pens per week (in thousands)

(b) Cigarette packs per week (in millions)

The first law of demand says that buyers will respond predictably to a price change, purchasing more when the price is lower than when the price is higher, if other things remain the same. The second law of demand says that the buyers' response will be greater after they have had time to adjust more fully to a price change.

TOTAL EXPENDITURE, TOTAL REVENUE, AND THE PRICE ELASTICITY OF DEMAND

In this section we examine the relationship between the price elasticity of demand and the total expenditure on an item (or revenue derived from its sale). Demand elasticity can be used to determine changes in total consumer expenditures at three levels: (1) for an individual's total spending on a product using the demand elasticity from an individual's demand curve for the product, (2) for the total combined expenditures of all consumers on a product using the elasticity from the total market demand curve for a product, or (3) for total consumer expenditures on the product of an individual business firm using the demand curve facing that firm.

If the price of a product rises, total consumer expenditures on it can either rise, fall, or stay the same, depending on the elasticity of demand. According to the law of demand, as the price rises the quantity purchased will fall, and as price falls the quantity purchased will rise:

$$\begin{array}{ccc} \text{Total Expenditures} & = & \text{Price} \times \text{Quantity} \\ ? & = & \uparrow \times \downarrow \\ ? & = & \downarrow \times \uparrow \end{array}$$

Because total expenditures are equal to price times quantity, and because price and quantity move in opposite directions, the net effect on total expenditures depends upon whether the (percent) price change or the (percent) quantity change is greater. When demand is inelastic, the price elasticity coefficient is less than one. This means that the percentage change in price is greater. ***Therefore, when demand is inelastic, a change in price will cause total expenditures to change in the same direction.***

When demand is elastic, the effect of the change in quantity will be greater than the effect of the change in price. ***Therefore, a change in price will cause total expenditures to move in the opposite direction when demand is elastic.***

When demand elasticity is unitary, the change in quantity will be equal in magnitude to the change in price. With regard to their impact on total expenditures, these two effects will exactly offset each other. ***Thus, when price elasticity of demand is equal to one, total expenditures will remain unchanged as price changes.***

The demand curves shown in Exhibit 6 can be used to illustrate the linkage between elasticity of demand and changes in total revenue. In the case of cigarettes (part b), the price elasticity of demand for the price increase from \$1.00 to \$1.50 is 0.26, indicating that demand is inelastic. This increase in cigarette prices leads to an increase in expenditures on the product from \$100 million (\$1.00 × 100 million units) to \$135 million (\$1.50 × 90 million units). If the change had occurred in the opposite direction, with the price falling from \$1.50 to \$1.00, total expenditures would have declined.

The price elasticity of demand for ballpoint pens for a price increase from \$1.00 to \$1.50 (part a of Exhibit 6) is 3.0, indicating that demand is elastic. This increase in the price of ballpoint pens leads to a reduction in total consumer expenditures from \$100,000 (\$1.00 × 100,000 pens) to \$37,500 (\$1.50 × 25,000 pens). If the change had occurred in the opposite direction, with the price falling from \$1.50 to \$1.00, total expenditures would have risen.

Exhibit 7 summarizes the relationship between changes in price and total expenditures for products with demands of varying elasticity. The (inelastic) demand for cigarettes